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Multianode Photo Multipliers for Ring Imaging Cherenkov Detectors

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Abstract

The 64-channel Multianode Photo Multiplier has been evaluated as a possible choice for the photo detectors of the LHCb Ring Imaging Cherenkov detector.

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1 Introduction

The LHCb experiment will exploit the large rates of B hadrons that will be produced at the Large Hadron Collider and make precision measurements of CP violation. Excellent particle identification is needed for LHCb, e.g. three kaons in a large momentum range are produced by the decay $B_s^0 \to D_s^{\mp} K^{\pm}$, $D_s^+ \to \phi\pi^+$, $\phi \to K^+K^-$ which is sensitive to the CP violating phase γ. Charged particles will be identified by means of two Ring Imaging Cherenkov (RICH) detectors. The RICH photo detectors must be sensitive to single photons with a quantum efficiency $\int QEdE \sim \mathcal{O}(1eV)$ and provide spatial resolution with a granularity of about 2.5 x 2.5 mm^2 over a large area of $\sim 3\text{m}^2$. The photo detectors must work in the magnetic fringe fields due to the LHCb dipole magnet and must cope with traversing charged particles.

2 Multianode Photo Multipliers

The multianode photo multiplier tube (MaPMT) consists of an array of 64 square anodes each with its own metal dynode chain incorporated into a single vacuum tube. The pixels have an area of 2.0×2.0 mm^2 and are separated by 0.3 mm gaps. The MaPMT, manufactured by Hamamatsu, has a 0.8 mm thick UV-glass window which transmits light down to a wavelength of 200 nm. The photons are converted in a Bialkali photo cathode with a quantum efficiency of maximum 22% at 380 nm. The mean gain of the 12-stage dynode chain is about 3×10^5 when operated at a voltage of 800 V.

The ratio of the sensitive photo cathode area to the total MaPMT area including the outer casing is only $\sim$ 48%. This geometrical coverage can be increased by placing a single lens with one refracting and one flat surface in front of each close-packed tube (Fig. 1). If the distance d of the refracting surface with radius-of-curvature R to the photo cathode is chosen to be equal to R the demagnification factor is $\approx 2/3$. Over the full aperture of the lens, light at normal incidence with respect to the photodetector plane is focused onto the photo cathode, thus restoring full geometrical acceptance.

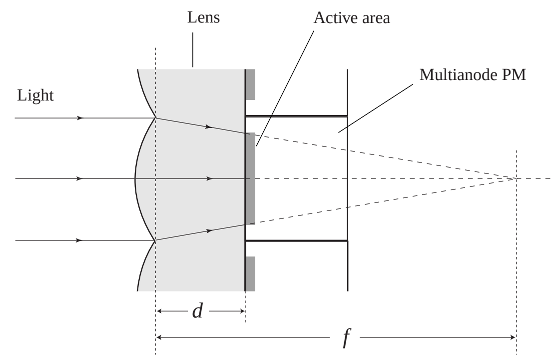

Figure 1: Schematic view of lens/MaPMT system. The focusing of normally incident light is illustrated.

3 R&D Results

The pulse height spectrum for the MaPMT is shown in Fig. 2, measured with a LED light source. The pedestal peak and the broad signal containing mostly one photo-electron are clearly visible. The signal to pedestal width ratio is 40:1.

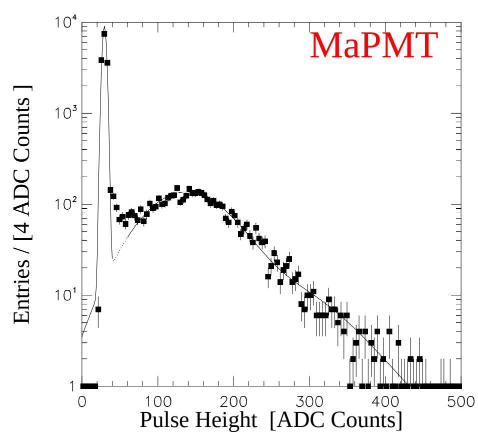

Figure 2: Pulse height spectrum of a pixel.

An array of 3x3 MaPMTs mounted onto the full-scale RICH 1 prototype[1] has been tested in a beam at the CERN SPS facility. The cathode voltage was set at -1000 V. Quartz lenses were mounted onto the front face of each MaPMT. The radiator was gaseous CF_4 at a pressure of 700 mbar.

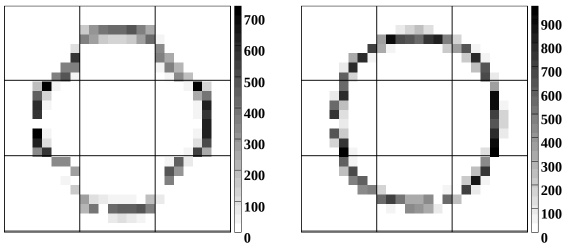

Figure 3: Cherenkov ring measured with the MaPMT array with (right plot) and without (left plot) quartz lenses mounted in front of the tubes.

The data were recorded with a pipelined electronic read-out system based on the APVm chip[2] and running at LHC speed (40 MHz).

The data analysis included a common-mode baseline subtraction on a event-by-event basis. With the pipelined read-out electronics cross-talk was observed. This has been investigated using LED runs and several sources -all in the electronics - were identified. The cross-talk is removed by rejecting signals in a pixel if there is a larger signal in one of its cross-talk partner pixels. Genuine double hits are lost by this procedure and the photon yield is corrected for it.

The integrated signals of two runs of 6000 events each are shown in Fig. 3, one with and one without the lenses in front of the MaPMTs. The Cherenkov ring is clearly visible and the effect of the lenses is nicely demonstrated. The gain in in photo electrons by employing the lenses is 45%. The background is small. We measure 6.51 ± 0.34 photo electrons which is is in good agreement with a full Monte Carlo simulation.

We have also exposed the MaPMT/lens to charged particles. The measured response is used to model the background in LHCb. The sensitivity of the MaPMT to magnetic fields has been studied. The MaPMT is affected by longitudinal magnetic fields but can be effectively shielded from the expected field strengths with a μ-metal structure.

4 Conclusions

We have successfully tested a 3x3 array of MaPMTs. Cherenkov light can be detected over the full area of closely packed tubes by means of quartz lenses focusing the light onto the sensitive area of the device. We have demonstrated that the MaPMT meets the performance requirements for charged particle identification in the LHCb experiment. The MaPMT has been chosen as the backup photo detector for LHCb.

Acknowledgments

I thank all my MaPMT collaborators for their excellent work presented here.

References

[1] E. Albrecht *et al.*, Nucl. Instr. and Meth. **A 411** (1998) 249.

[2] L.L. Jones *et al.*, "Electronics for LHC Experiments", Rome 1998, CERN/LHCC/98–36 (1998) 185.